Technical Report 65-4

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Functional and Appearance Fidelity of Training Devices for Fixed-Procedures Tasks

by

*John A. Cox, Robert O. Wood, Jr.,
Lynn M. Boren, and H. Walter Thorne*

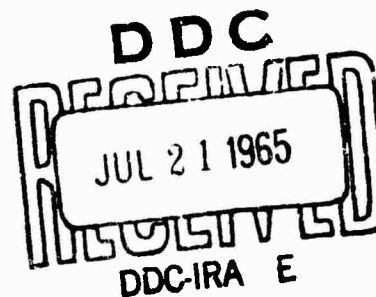HumRRO Division No. 5 'Air Defense'

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**The George Washington University
HUMAN RESOURCES RESEARCH OFFICE
operating under contract with
THE DEPARTMENT OF THE ARMY**

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Technical Report 65-4
Task RINGER

FOREWORD

Research in HumRRO's Task RINGER, Fidelity Requirements for Training Devices, is completed with the publication of this report. The research objective was to determine the effect on task proficiency of reducing the functional fidelity and appearance fidelity of training devices. A series of experimental studies on a fixed-procedure task, in which device fidelity was varied in a number of ways, was followed by a field test to confirm the findings under conditions typical of Army instruction.

HumRRO research efforts are conducted under Army Contract DA 44-188-ARO-2, with Task RINGER work performed under Army Project No. 2J024701A712 03, Training Devices. Task RINGER research was performed by HumRRO Division No. 5 (Air Defense) at Fort Bliss, Texas. The Director of Research is Dr. Robert D. Baldwin.

Military support for the research was supplied by U.S. Army Air Defense Human Research Unit. Lt. Col. Leo M. Blanchett, Jr., is the Unit Chief.

MEREDITH P. CRAWFORD
Director
Human Resources Research Office

Military Problem

In considering the characteristics that would make a training device an effective component in a training program, a central question is that of fidelity—the degree to which the device should resemble the tactical equipment for which the device is substituted in training. Since high fidelity simulation tends to be expensive, training device costs can be substantially reduced if devices of less-than-perfect fidelity can be used for training with little or no loss in proficiency development and little or no increase in training time.

Research Problem

Research was performed to determine the effects on proficiency development of using devices of less-than-perfect fidelity for training men to perform a lengthy fixed procedure. In a series of experiments the fidelity of training devices was lowered in either functional or appearance quality. A fixed procedure was defined as a part of a job in which all signals to, and actions by, the incumbent are specified in an invariable sequence and are simple enough that a trainee either will already know, or can readily learn, how to perform each individual step.

Procedure

The Task. A 92-step procedure, considered to be representative of procedural tasks in general, was used as an example of a fixed-procedure task for this research. This procedure concerned the operation of the Section Control Indicator (SCI) console of the Nike Hercules guided missile system when missiles are being prepared for firing (Blue Status) and being fired (Red Status).

Training Devices. Twelve training devices were used in the experiments:

Hot Panel. This device was the same size and shape as the tactical SCI. Every light, switch, meter, intercom, and telephone on this device functioned (see Fig. 2).

Cold Panel. On this device, every part was identical with the corresponding part on the Hot panel. However, there was no electrical power to the device, so no lights, meters, intercom, or telephone functioned. All switches still could be operated (see Fig. 3).

Frozen Panel. Every part on the Frozen panel was identical in appearance with the corresponding part on the Hot panel, but no part was operable. All switches were immovably fixed in OFF position (see Fig. 4).

Cardboard Panel. The entire device, including the housing, was fabricated of cardboard. The panel was painted to resemble the color of the Hot panel, and the remainder was painted the same gray color as that of the other device housings (see Fig. 10).

Photographic Panel. This device was a full-size black-and-white photographic print of the Hot panel, installed in a high fidelity housing (see Fig. 5).

Drawing Panel. This device was a full-size black-and-white line drawing of the Hot panel, installed in a high fidelity housing (see Fig. 6).

High Fidelity Housing. This device was a replica of the housing of the Hot panel. The Cold panel was installed in the device during the study of housing effects (see Fig. 7).

Box Housing. This device was a box made of plywood. It was of appropriate size and shape to hold the Cold panel, which was installed in the device for the housing study (see Fig. 8).

Frame Housing. This device was a simple wooden frame of appropriate size to hold and support the Cold panel (see Fig. 9).

Full-Sized Panel. This device was another black-and-white line drawing on which the lettering was increased in size. The panel was 22" x 30" (see Fig. 11-A)

Half-Sized Panel. This device was a 15" x 22" reproduction of the Full-Sized panel (see Fig. 11-B).

Small Panel. This device was a 5" x 7" reproduction of the Full-Sized panel and was one-nineteenth the area of the Full-Sized panel (see Fig. 11-C).

Results

Five-man groups were trained with each of the above training devices until 15 or 20 men had been trained with each device. Each trainee was administered a proficiency test, and his total training time was recorded. The small differences in average (mean) proficiency scores and average training times that were found among the several devices are illustrated in Figures A and B. Statistical analyses showed that none of the differences in average proficiency or average training time were statistically significant. Men trained on low fidelity devices were as proficient as those trained with devices high in functional and appearance fidelity.

A field test of the above findings was performed, in which military instructors trained soldiers to perform this task as part of Advanced Individual Training for Military Occupational Specialty (MOS) 177. Some instructors used the actual live equipment during this training while other instructors used the full-sized line drawing of the panel. Only chance differences were found between the average proficiency scores or training times of the men trained under both conditions. The results of other research were compared to the above findings and largely tend to confirm them.

Conclusions

1. When men are being trained to perform a fixed procedure, the requirements for functional fidelity in the training device are quite low. A line drawing of the man-machine interface will train men as effectively in this circumstance as will a device of higher fidelity.

2. No effect on proficiency development is likely to occur as a result of reducing the housing fidelity of the man-machine interface on a training device. The least expensive housing that will adequately support and protect the man-machine interface should be used.

3. Lowering the fidelity of a training device by reducing its size has no effect on proficiency development, so long as the parts of the device remain clearly visible to the individual trainee.

Comparison of Average Proficiency Level Produced With Twelve Training Devices

Training Device

Mean Proficiency Score
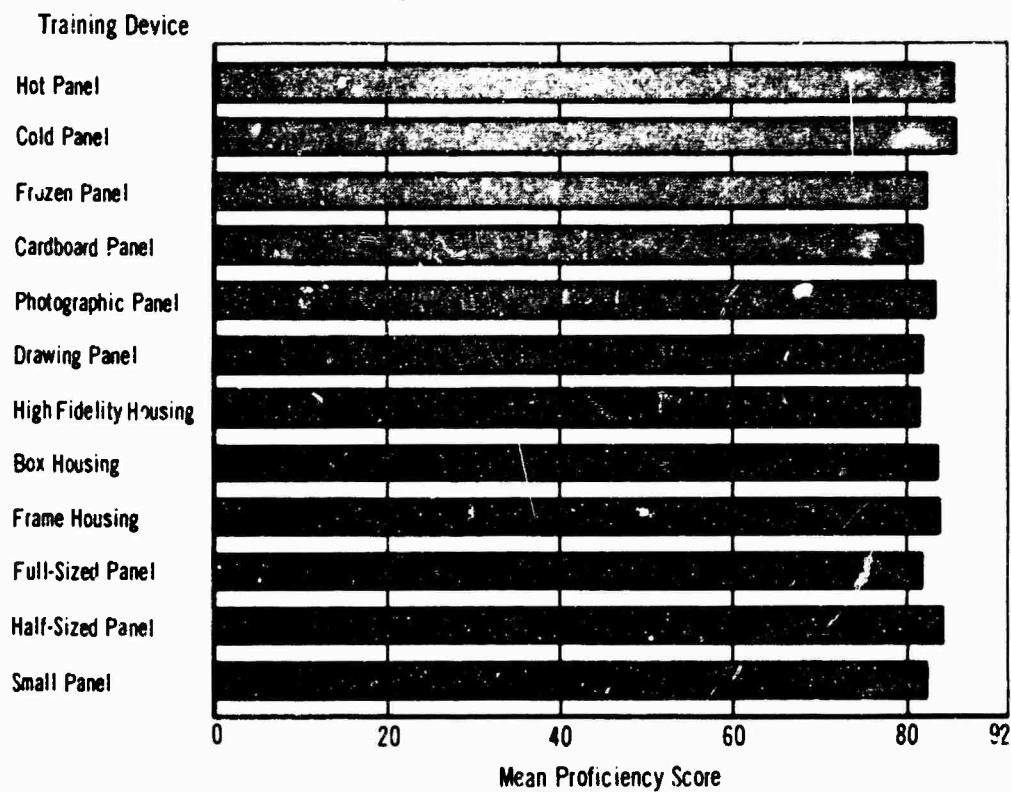
Figure A

Comparison of Average Time Required to Train With Each of Nine Training Devices

Training Device

Average Training Time (Hours)

Figure B

CONTENTS

Functional and Appearance Fidelity of Training Devices for Fixed-Procedures Tasks

INTRODUCTION

Purpose of the Research

In the effort to insure that trainees will meet the established training objectives, selection of appropriate methods greatly enhances the effectiveness of a training program. Use of a training device is a method that is especially useful when trainees must learn and practice actions.

In deciding whether to use a training device or some other method, the designer of training programs can obtain considerable guidance from such sources as Gagné (5), Miller (9), Demaree (2), Parker and Downs (11), and Willis and Peterson (16). Fewer guidelines are available to him when, having decided to use a training device, he is faced with questions concerning the technical characteristics it should have. A central question will deal with fidelity—the degree to which the device resembles the tactical equipment for which the device is to be substituted.

Task RINGER has the objective of determining the fidelity requirements of training devices for fixed-procedures tasks. For this research, a fixed-procedure task is defined as a part of a job in which all signals to the incumbent and actions by the incumbent are specified in an invariable sequence. The research was conducted at the U.S. Army Air Defense Human Research Unit[1] at Fort Bliss, Texas, beginning in 1963.

Training Device Fidelity

For many years, studies on transfer of training have shown that the more alike two situations are, the more training in one situation will produce proper performance in the second situation. Bugelski, for example, notes that ". . . experimental findings indicate that positive transfer is a function of the degree of similarity between stimuli (if responses are the same), and negative transfer is a function of the degree of difference between responses if the stimuli are the same" (1, p. 408).

The obvious conclusion would be: "For maximum transfer of training, use devices of perfect fidelity." However, more recently, the older research findings have come to be suspect; devices having less-than-perfect fidelity have been found to produce the maximum transfer

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[1]As of 1 January 1965, the HumRRO research contingent of the Air Defense HRU was designated as HumRRO Division No. 5 (Air Defense).

(10, pp. 129-132). Also, the costs associated with high fidelity simulation have become a matter of concern (9, 10, 11). If it can be determined that devices of less-than-perfect fidelity can be used for training with no more than a minor loss in proficiency development, and no more than a minor increase in training time, practical reductions in the costs of training devices may be realized.

The definition of fidelity of simulation has eluded the human factors scientist for some time (10, p. 103). There is need for some scheme for measuring degree of fidelity or deviation from the original. The work described in this report is based on a concept that recognizes fidelity as having several dimensions. One group of these dimensions, termed appearance fidelity, includes such factors as color, size, shape, arrangement of parts, and the container or housing of the man-machine interface. However, even if appearance fidelity is high, training devices can be differentiated according to degree of functionality. A knob or meter may look exactly the same on one device as on another, but on device A the knob moves and produces an equipment effect, on device B the knob moves but produces no effect, while on device C the knob will not move.

Task RINGER experimentation dealt with functional characteristics and with appearance categories such as size and housing. Measurements of functional or appearance fidelity were relatively gross; no attempt was made to scale the amount of the differences in psychological terms.

RESEARCH PLAN

The basic plan of the studies described in this report has six elements:

 (1) A task that was considered to be representative of procedural tasks in general was chosen as a vehicle for the studies.

 (2) Training devices were constructed which varied from one another on the particular dimension of fidelity being studied.

 (3) Groups of men were trained with the several training devices.

 (4) Experimental controls were applied on such factors as intelligence level of trainees, instructor effects, methods used in training (other than training device), and level of trainee experience with respect to the task

 (5) Trainee proficiency was tested.

 (6) The data were tested for differences in proficiency which were associated with the training devices located at different points on the particular fidelity dimension.

Since each of the separate studies had much of the above material in common, the common factors are described in this section and

should be understood to apply to each of the studies unless some variation is noted in the description of a particular study.

In the first five studies, various appearance and fidelity dimensions of the devices were varied under closely controlled conditions. The sixth experiment was a field study conducted under more realistic Army training conditions.

The Procedural Task

For these studies, a procedural task was viewed as work in which every action is specified in sequence and is so simple, or so well known, that any trainee for the job will either already know how to do it or can learn it in one trial. The learning demands placed on the trainee are to learn the sequence in which the actions are taken and the names and/or locations of events in the sequence; he must perform each action in its turn and avoid taking any action out of turn.

The task chosen was one that fulfilled the above definition, was long enough to present a challenge to any trainee yet short enough to be economical during data collection, and was performed at a place geographically convenient to the investigators. It was selected from the tasks performed by Military Occupational Specialty (MOS) 177, Air Defense Missile Crewman, Nike Hercules.

The task consisted of the actions taken by the operator of the Section Control Indicator (SCI) during Blue and Red Status when the system operates in the automatic mode. (During Blue Status, missiles are prepared for firing, and during Red Status they are fired.) During this procedure 92 actions are taken. The kinds of actions and the frequency of their occurrence in the sequence are:

Action	Frequency
Operating a button switch	8
Operating a toggle switch	29
Operating a rotary switch	2
Operating a rheostat control	2
Operating a banana plug	1
Writing the time	3
Giving a verbal response on phone or intercom	11
Monitoring a light	18
Monitoring a sound, oral or machine originated	16
Monitoring a meter	2

In each step the operator receives a signal and must take a specific action as a result of the signal. Sometimes the signal for an action is simply the completion of the previous action, and sometimes the action to be taken is only to monitor for the next signal. But psychologically each such unit, signal and action, is a complete step in this procedure.

The full procedure is given in Appendix A. A picture of the tactical SCI is presented in Figure 1.

Tactical Section Control Indicator (SCI)
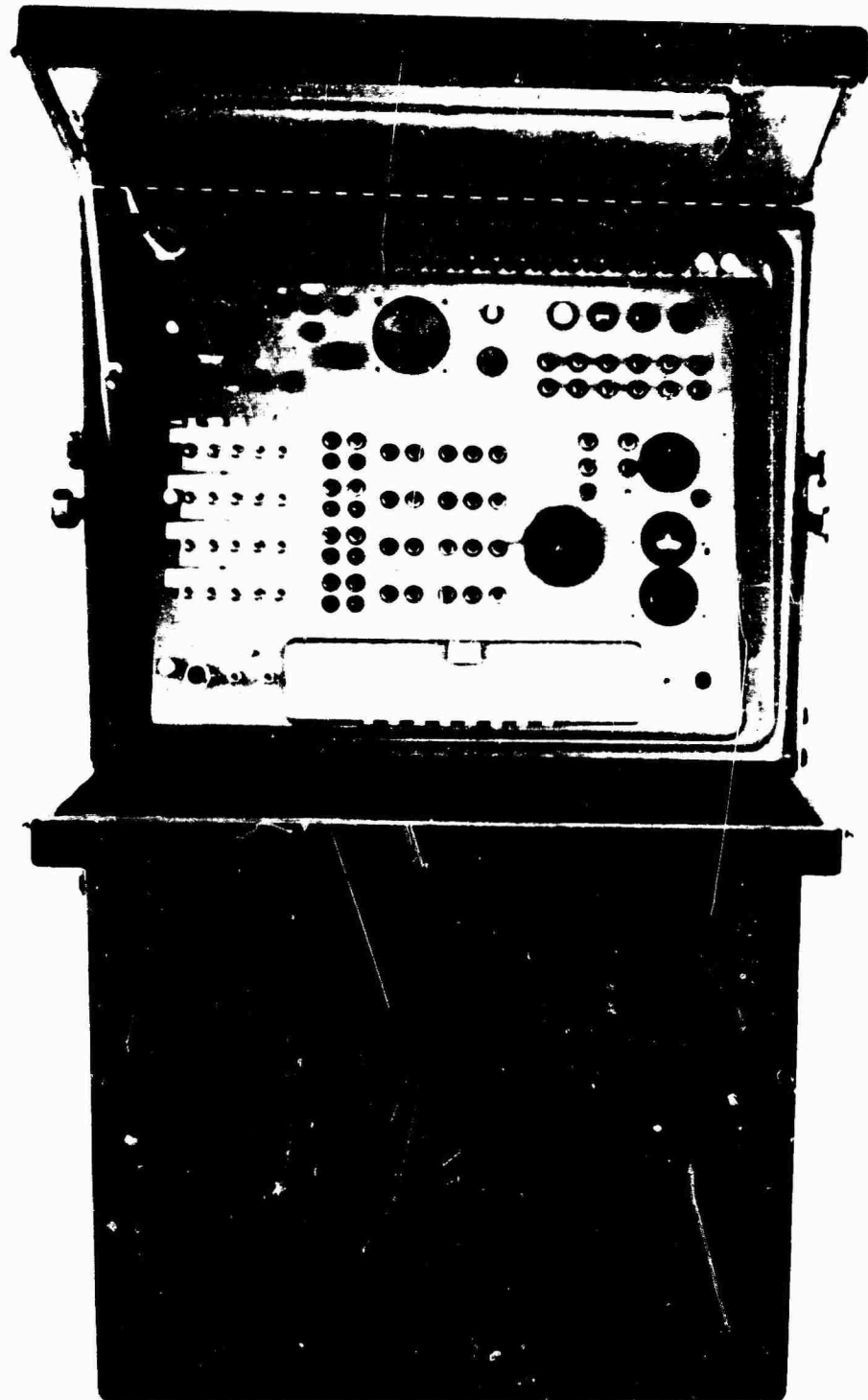
Figure 1

Training Devices

Twelve different training devices were constructed for use in the studies. Each one is pictured and described briefly on the following pages:

High Fidelity SCI Simulator (Hot Panel)
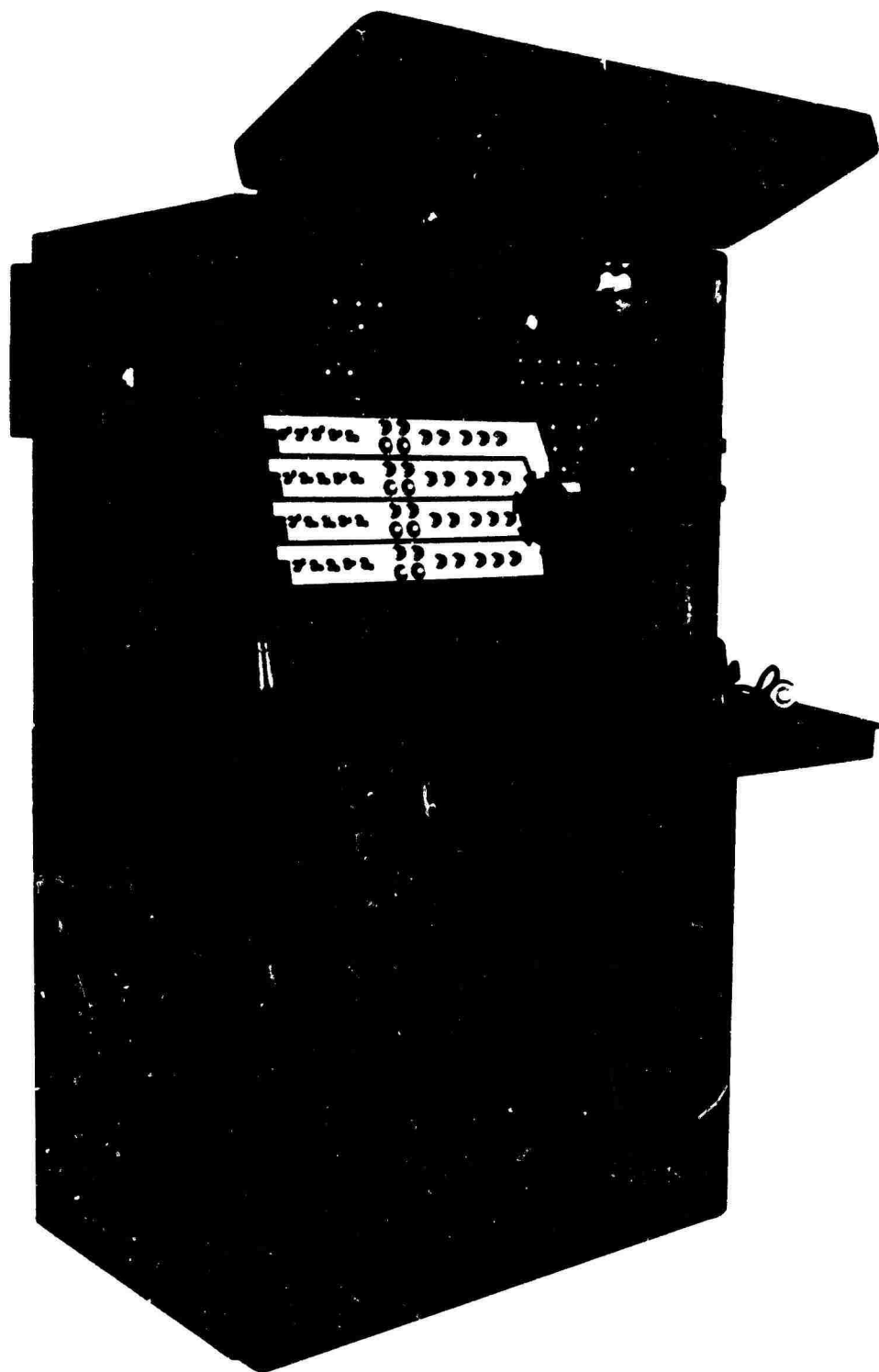
Figure 2

This device, which consisted of panel and housing, simulated the tactical SCI with more fidelity than any of the others. It was the same size and shape as the SCI and fully functional; every light, switch, and meter, and the intercom and Handset-Headset operated. Appropriate sounds were provided, and it even observed the same time delays as the tactical SCI.

Cold Panel
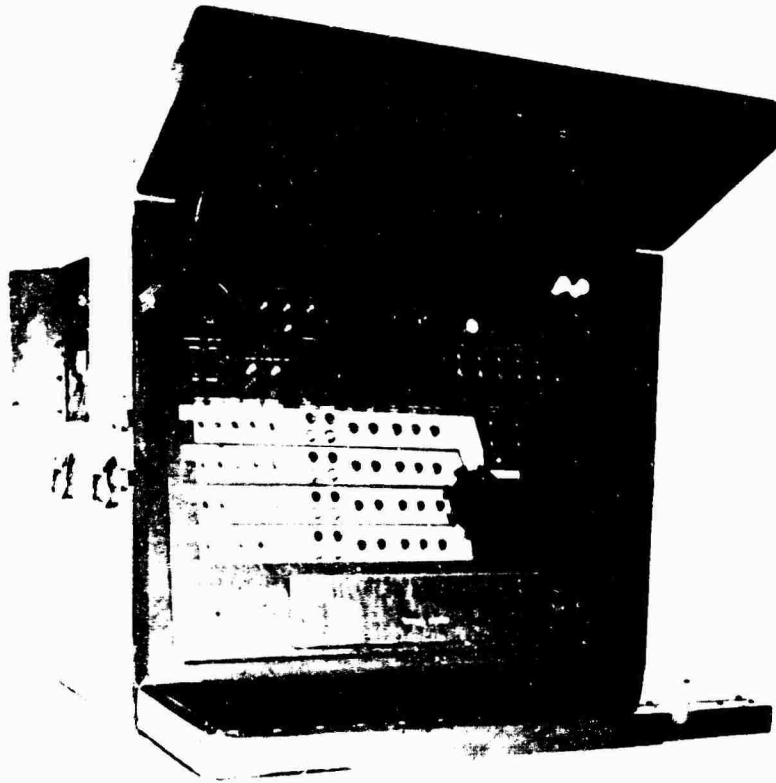
Figure 3

The oppearonce fidelity of this device wos high but its functionol fidelity wos limited. Every part of the Cold ponel was identicol in size and oppearance with its corresponding port on the Hot panel. The Cold ponel, however, had no electricol power; none of its lights could be illuminated ond meters did not register. The intercom ond Handset-Headset did not operote, although the latter could be plugged into the ponel foce. All switches ond buttons were functionol to the extent that they moved properly when turned or pressed, but they hod no octivoting effect.

Frozen Panel
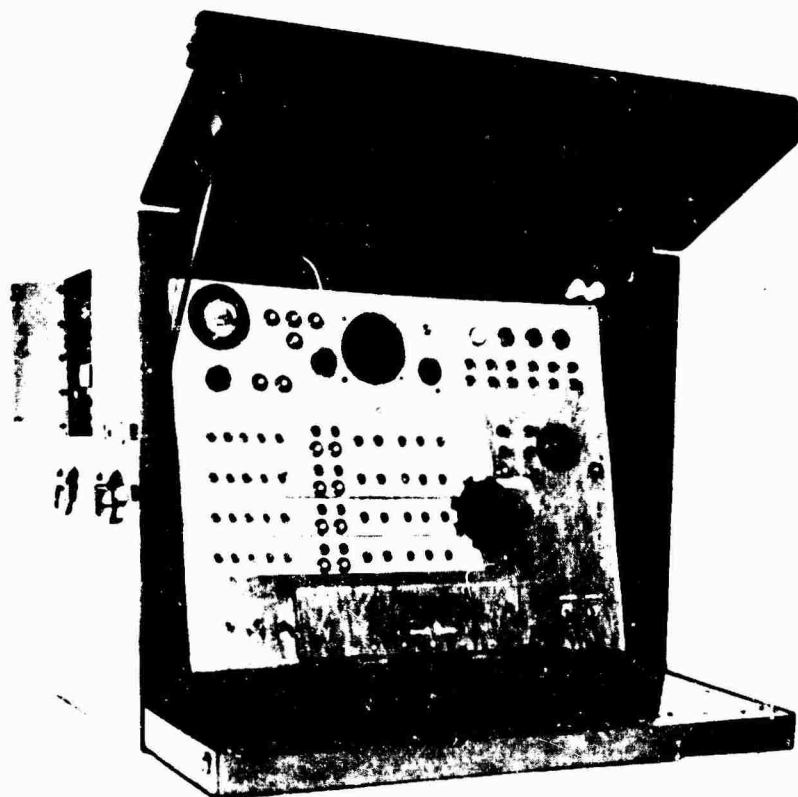
Figure 4

The functionol fidelity of this device wos the lowest of those that were three-dimensionol. Its oppearonce wos identical with the Hot ponel, but none of the lights or meters, or the intercom or Handset-Heodset functioned, nor did ony of the switches operate; eoch wos immovobly fixed in OFF position.

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Photographic Panel
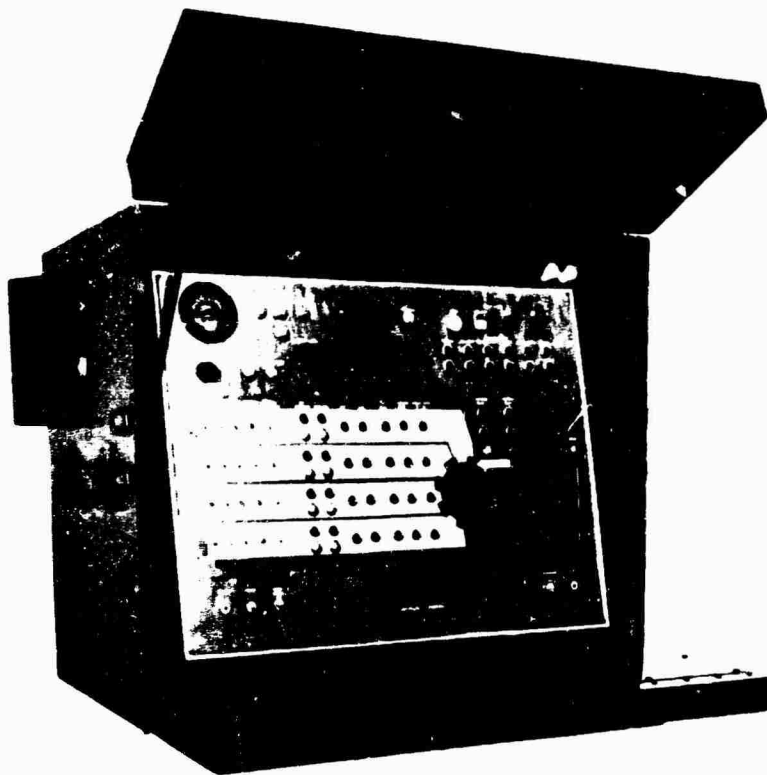
This device, mounted on plywood, was a full-sized black-and-white photographic print of the Hot panel.

Figure 5

Drawing Panel
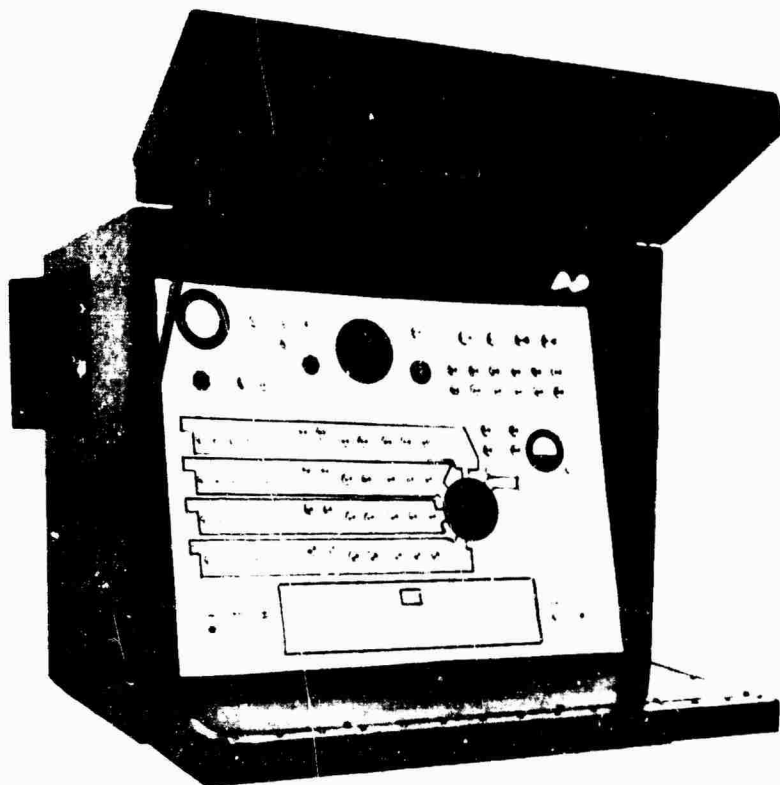
This device, mounted on plywood and shielded with plastic, was a full-sized black-and-white line drawing of the Hot panel. The size and placement of each part was as nearly like that of the Hot panel as possible.

Figure 6

High Fidelity Housing

Figure 7

This device was a handmade wooden replica of the wooden housing of the Hot panel and was painted the same gray color. It held the Cold panel during training.

Box Housing
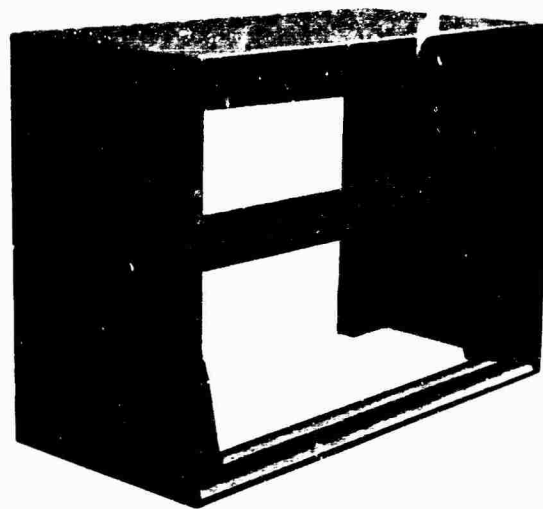
Figure 8

The fidelity of this device was lower than that of the High Fidelity housing, being a box made of plywood, painted gray to match the color of the High Fidelity housing. Its size and shape fitted the Cold panel and concealed the back of the panel during training.

Frame Housing

This device had the lowest fidelity of any housing used in the studies. It was a simple wooden frame that supported the Cold panel, but did not conceal its back.
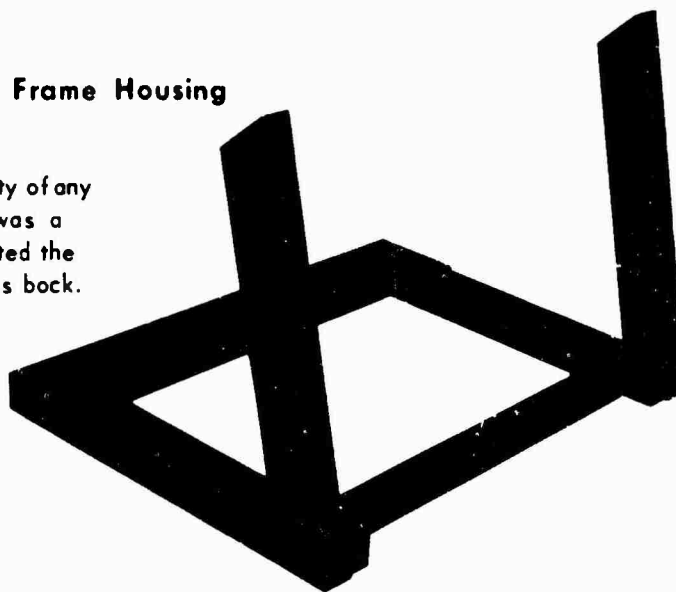
Figure 9

Cardboard Panel
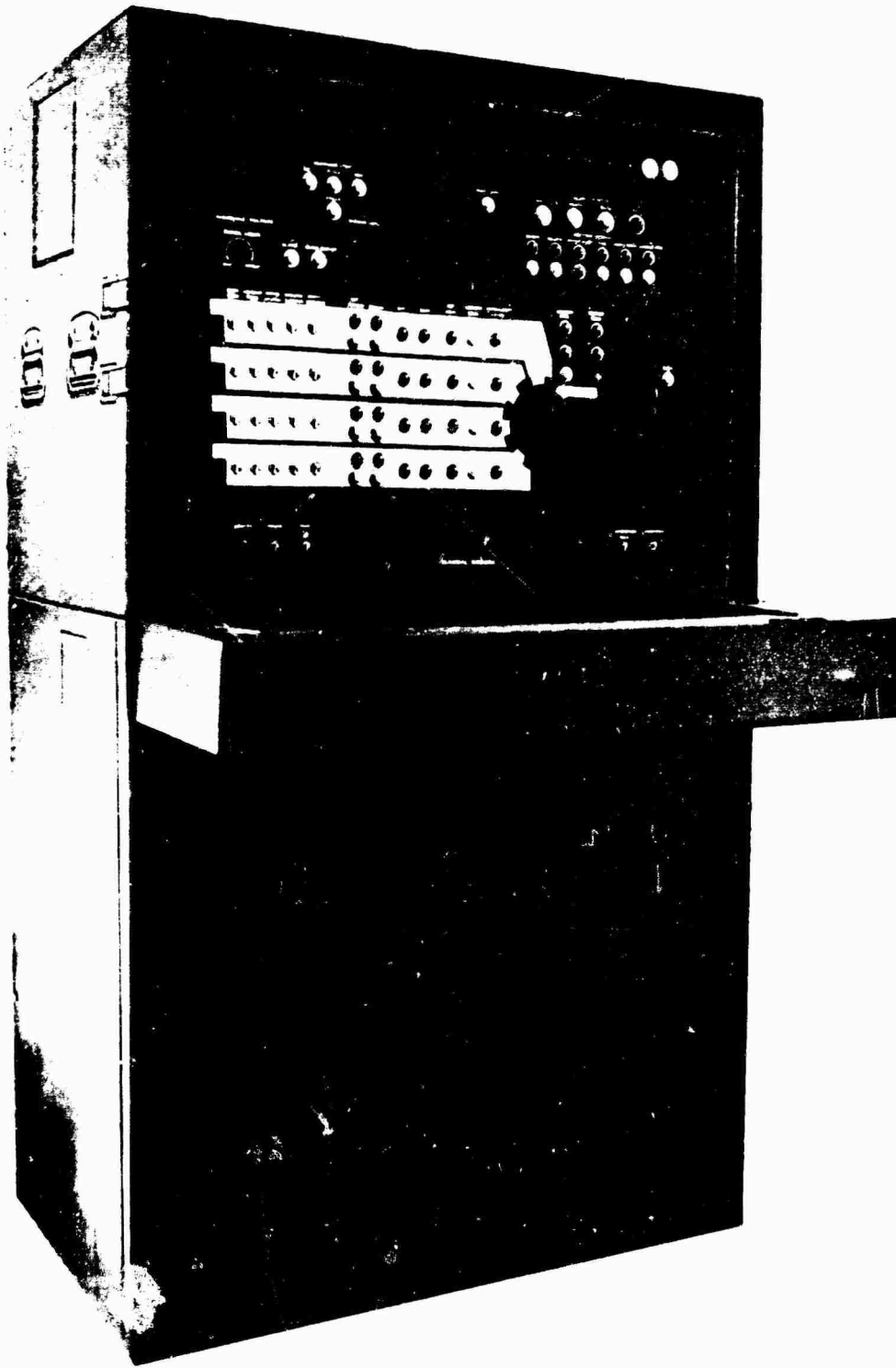
Figure 10

Both the functional and the appearance fidelity of this device, which consisted of panel and housing, were lower than the devices previously described because it was fabricated entirely of cardboard. The panel was two-dimensional, drawn to scale, and painted in color to resemble an illuminated Hot panel. The housing was printed the same gray as the housing of the Hot panel.

Relative Sizes of the Three Panels for Study V
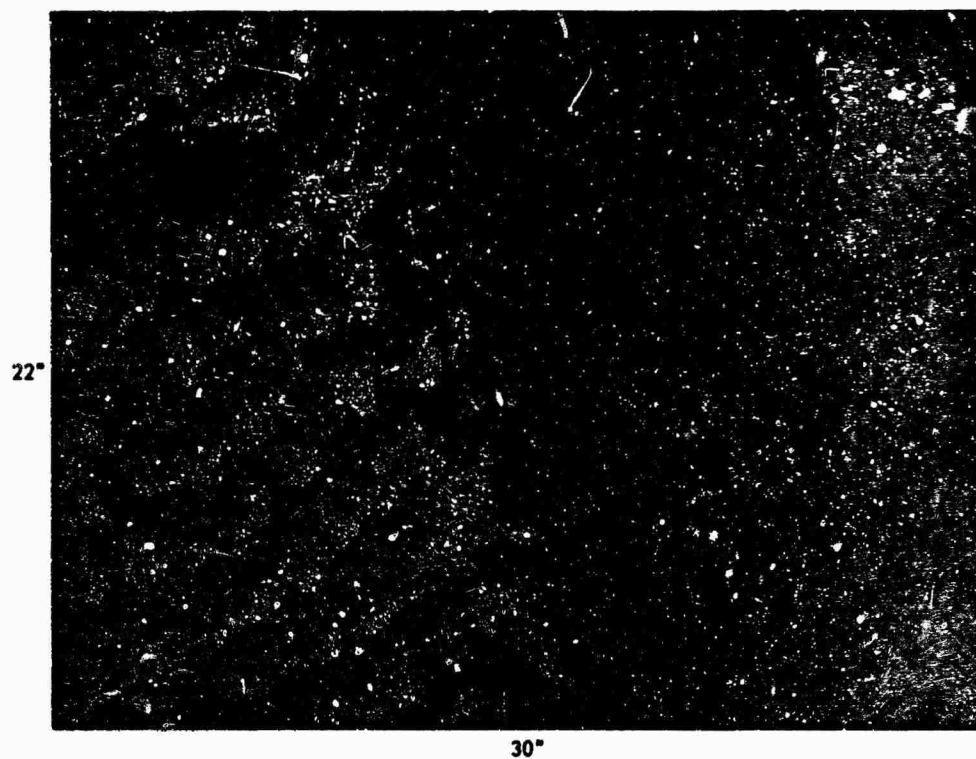
A. Full-Sized Panel—This device was a line drawing, identical in every way with the Drawing panel except that the lettering was larger than on the Drawing panel. It measured 22 x 30 inches.

C. Small Panel—This device was a reproduction of the Full-Sized panel reduced to 5 x 7 inches—one-nineteenth the size of the Full-Sized device.

B. Half-Sized Panel—This device was a reproduction of the Full-Sized panel reduced to 15 x 22 inches—one-half the size of the Full-Sized panel.

Figure 11

Training

Trainees

Men receiving training in MOS 177 were not used as trainees in the first five studies since such trainees would have varying amounts of information about the task selected from this MOS. In these experiments men were used who were receiving training in MOS 192, Air Defense Artillery Automatic Weapons Crewmen. In the field study (Study VI) MOS 177 trainees were used.

As a basis for selecting MOS 192 trainees comparable to men in MOS 177 training, the General Technical (GT) scores from the Army aptitude area scores were obtained from personnel records for all men in training for MOS 177, and a distribution of these scores was made (Table 1). Trainees for MOS 192 were then selected in groups whose GT scores matched the GT score distribution of the MOS 177 sample.

Table 1

Distribution of Subjects Over the Range of GT Scores

Range of GT Scores	Distribution Among MOS 177 Trainees (N = 65)	Distribution in Panel Sample	
		15-Man Group	20-Man Group
80 and below	6	1	2
81 to 90	18	5	6
91 to 100	11	3	3
101 to 110	10	2	3
111 to 120	10	2	3
121 to 130	5	1	2
131 and above	5	1	1

The GT score was chosen for selecting trainees because, of the Army aptitude area scores, it is the most like a measure of general intelligence (7) and hence seemed to be the most meaningful element. Selection on only one aptitude variable was considered useful because the positive correlations among the several aptitude scores produces diminishing returns as control with additional variables is applied.

Instructors

Four research employees of the U.S. Army Air Defense Human Research Unit served as instructors for the first five studie

Procedures

Men were trained in five-man groups. The instructor informed the trainees that he would teach them to operate a piece of Nike Hercules equipment and identified the SCI. He then showed a diagram of a Nike Hercules site and identified each major piece of equipment, giving a brief description of its function. (See Appendix B for the diagram and orientation.) He asked the trainees if they had any questions and answered as directly as possible the few questions that were asked.

The instructor then moved to the training device and presented a demonstration talk-through of the 92-step procedure. He demonstrated and described the signal for an action, and the action itself, and gave a very simple explanation of why the action was taken. For example, the first signal was the simultaneous illumination of a Blue Status light and sounding of an alarm buzzer, and the proper action was to turn the Power switch to ON position. The explanation given was, "You turn the Power switch ON so that you will have power to this panel."

When the 92-step demonstration was completed, the instructor selected a trainee to attempt to perform the procedure. The other four trainees were told to watch carefully and to be prepared to identify the correct action if the performing trainee made an error. When the performer made an error, the instructor usually asked an observer to identify the correct action and required the performer to carry it out. The performer continued until he had accomplished all 92 steps. Then a second trainee was selected to perform on the training device, the first trainee becoming an observer. Each trainee performed twice and observed eight times.

During this training the instructor used such verbal expressions as "Good" and "That's right" to reinforce correct actions. Not every correct action was reinforced, and no attempt was made to follow an exact schedule, but the technique was used more frequently in the early stages of training than in the later stages.

The instructors also used cueing as a training technique. When a performing trainee hesitated to take some specific action after he had apparently recognized the signal, the instructor would attempt to give a cue (or clue) to the correct action. For example, completion of the seventh action ("Plug the Headset-Handset into Station 2") is the signal for the eighth action to be taken; the operator should announce on the Headset-Handset, "Blue Status received, Section A." If a trainee completed action seven and hesitated too long to make his announcement, the instructor might say, "You plugged it in, now use it." Cueing was used much more often in the early part of training than in the later part, with each instructor trying to estimate the proper time for a cue and an appropriate cue to use.

The tactical SCI automatically furnishes knowledge of results to an operator after many of his actions. Thus, when the operator presses the Prepared button for Launcher 1, the red Prepared light goes out, and the green Prepared light goes on. Only one of the training devices, the Hot panel, gave trainees the same knowledge of results as does the tactical SCI. For the other devices, the instructor gave the performing trainee this information on a verbal basis. In the above instance, when a trainee pressed the Prepared button the instructor would say, "Now this red light is off, and this green light is on," and would point to the proper lights.

Similarly, on most of the devices the trainees were required to "speak" an action instead of performing it physically. Thus, as the action for step 62 the trainee monitored for a green Missile Ready-to-Fire light. If, on the training device, the light could not be illuminated, a trainee had to tell the instructor, "Now I am waiting for the Missile

Ready-to-Fire light for Launcher 1 to come on," or make some similar statement to indicate that he was taking the proper action (monitoring).

Training time varied from group to group. The experiences that each group underwent were controlled, but the total amount of time spent in the training situation was allowed to vary. At no time was the trainee made to feel that he was rushed.

The sessions began at 07 10 and lasted about three hours. Except for one rest break approximately half way through the training period, the training was continuous.

All training was conducted in a room approximately 10 feet wide and 15 feet long. Other activities were going on inside the building, but not in the same room. The room was heated with a gas heater during cool weather and cooled with an evaporative cooler in hot weather.

Experimental Controls

Controls were applied to keep the intellectual level of the trainees from influencing the results of the experiments. As previously described, each group of men trained with any device was selected to match a particular distribution of GT scores.

To reduce differences among the instructors, the training procedure was practiced at length and the instructors observed each other during practice.

The method of training was controlled by specifying exactly the orientation, demonstration, and use of training devices. Along with the training methods, each instructor practiced reinforcement, cueing, and providing verbal knowledge of results until he was proficient.

The experience level of trainees with respect to the task to be learned was controlled by using only men from another MOS, who were naive with respect to Nike Hercules and knew nothing of the task before training began.

Statistical controls used to remove variances due to different GT levels or instructors are described under Study I.

Proficiency Measurement

After the subjects had been trained, they were tested to see how well they had learned the procedure from the training device they had used. Their proficiency was tested on the Hot panel device, which was a high fidelity, fully functional simulator of the SCI. For the purposes of this research, the Hot panel device was considered equivalent to the tactical SCI and the relative effectiveness of other training devices was evaluated by testing the trainees on this panel.

For the proficiency test, a trainee was told that he was to perform the 92-step procedure using the Hot panel and that all parts of the device operated. Then the instructor operated a switch that turned on the Blue Status light and the alarm buzzer, and the trainee began the procedure he had learned. The instructor operated his console and kept a record of the trainee's errors. Each step omitted or taken out of sequence constituted an error. Any question asked by the trainee was

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answered and an error was recorded for that step. If the trainee made an error that would have prevented continuance, the instructor corrected that error and recorded it, allowing the trainee to continue the test. The proficiency score was the number of steps performed correctly.

The trainee was told that he was to be scored on accurate performance and that time was not a factor on this test. Actually, total test time was recorded along with the proficiency score. Approximately 10 minutes were required to test one trainee.

Each trainee was tested in the same room and in the same order in which he had performed during training, with only the instructor present during the test. Testing was done between 1300 and 1400 hours on the same day on which the training had taken place.

FUNCTIONAL FIDELITY—STUDY I

Plan of Study

In this study, a test was made of the effects of three levels of functional fidelity in training devices used to teach trainees a procedural task. Fidelity was measured on a nominal scale; no assumptions were made about the psychological distances between the categories.

The three training devices used in this experiment were the Hot panel, the Cold panel, and the Frozen panel, all of which had high appearance fidelity. The Hot panel also had high functional fidelity. On the Cold panel various switches and other parts could be operated but did not activate the equipment, while on the Frozen panel there were no movable parts.

On each of the devices 20 men, in four groups of 5 men each, were trained to perform the 92-step procedure. Two instructors each trained one 5-man group and a third instructor trained two 5-man groups with each device. Each instructor administered proficiency tests to those men whom he trained.

Analysis and Results

After adjustment for variation associated with GT scores,[1] the proficiency scores were tested for differences related to the use of the three different panels, differences owing to the three instructors, and interaction effects associated with panels by instructors.

The general level of difficulty of the task is indicated by the fact that the overall proficiency score mean was 84.7 out of a possible total of 92. When the effects of intelligence (as measured by GT) were removed from the proficiency scores, no differences in proficiency were found that were associated with training devices, instructors, or interaction between devices and instructors ($p > .05$).[2]

[1]Tests of homogeneity of regression were performed to assess the legitimacy of this analysis. In each case, the tests did not lead to rejection of null hypothesis of homogeneous regression.

[2]When this set of studies was being planned, each study was to use an N of 20, and the .05 level of significance was selected for rejection of the null hypothesis. After Studies I and II were completed, it was decided to reduce the sample size to 15 for each subsequent study. To compensate for the effects of using a smaller sample, the .10 level of significance was selected for the remaining studies.

The individual proficiency scores are presented by training groups in Table 2. Results of the covariance analysis are presented in Appendix Table C-1, and the unadjusted and adjusted mean proficiency scores, by device and instructor, are in Table C-2.

Table 2

Individual Proficiency Scores[a] of Trainees by Training Group: Study I

	Hot Panel (N = 20)	Cold Panel (N = 20)	Frozen Panel (N = 20)
	92	92	92
	92	92	92
	92	91	91
	92	91	91
	91	91	89
	91	90	89
	91	89	88
	91	89	87
	91	89	85
	90	88	84
	89	88	83
	89	86	83
	88	85	83
	88	85	63
	88	84	82
	87	84	81
	86	81	74
	70	79	69
	60	74	68
	57	70	54
Mean	85.8	85.9	82.4
Median	89.5	88.0	83.5

[a] Highest score possible: 92.

The mean group training time was 2 hours, 41 minutes[1]; the fastest group completed training in 2 hours, 15 minutes, while the slowest group required 3 hours, 30 minutes. The training time means for panels and instructors are presented in Appendix Table C-3. An analysis of variance (8, p. 156), performed to determine whether there were significant differences among training times for panels and instructor groups, showed that differences were within chance expectation.

Study I thus demonstrated that reducing the functional fidelity of a device to the point where the device was not operational did not affect proficiency in a procedural task. Trainees were able to learn as well when trained with the Frozen panel as when trained with the Hot panel.

[1] Since the mean training time for each group was not significantly correlated with the mean GT score for the group ($r = .22$, $p > .05$), a covariance analysis of training time scores was not considered to be either necessary or useful.

TWO-DIMENSIONAL VS.
THREE-DIMENSIONAL DEVICES—STUDY II

Plan of Study

While the Frozen panel used for Study I training was not operative, trainees could and did reach out and hardle the various switches and knobs on the panel face. Thus, a panel which was a flat surface would represent a lower degree of functional fidelity than the Frozen panel because the flat surface would reduce sensory effects from touch and kinesthesis. It would also represent a lower degree of appearance fidelity.

Following this line of reasoning, the Photographic panel and the Drawing panel, both two-dimensional devices, were introduced in Study II in order to compare the effects of training on these lower fidelity devices with those of the three-dimensional devices, Hot panel and Frozen panel.

Since there are appearance differences between each of the two-dimensional devices and any one of the three-dimensional devices, there is some confounding of appearance fidelity and functional fidelity in this study.

The data collected for the Hot panel and Frozen panel of Study I were used again in this study. Collection of data with the Photographic and Drawing panels followed the pattern described for Study I. Twenty men, in four 5-man groups, were trained with each device. Two instructors trained one 5-man group with each panel, while the third instructor trained two groups with each panel.

Analysis and Results

An analysis of covariance was performed on the proficiency scores,[1] intelligence being controlled with GT scores. The proficiency scores were tested for differences owing to panels and instructors, and effects of panels by instructors' interaction. The results of this analysis (Appendix Table C-4) show that none of the above factors produced differences among adjusted proficiency scores larger than chance. The overall unadjusted mean proficiency score was 83.5 (Table 3). Proficiency score means, by device and instructor, are shown in Appendix Table C-5.

As in the first study, training time was found to be uncorrelated with GT scores (r = .11, p > .05). An analysis of variance showed that no significant differences in training times can be attributed to different instructors or to the use of different panels. The fastest group completed training in 2 hours, 15 minutes, the slowest group in 3 hours, 30 minutes, and the mean training time was 2 hours, 48 minutes. Appendix Table C-6 presents the mean training times for instructors and panels.

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[1]Tests of homogeneity of regression were performed. In each case, the tests did not lead to rejection of the null hypothesis of homogeneous regression.

Table 3

Individual Proficiency Scores of Trainees by Training Group: Study II

Hot Panel (N = 20)	Frozen Panel (N = 20)	Photographic Panel (N = 20)	Drawing Panel (N = 20)
92	92	90	91
92	92	90	91
92	91	90	91
92	91	89	90
91	89	88	89
91	89	88	88
91	88	87	87
91	87	86	87
91	86	86	87
90	84	86	86
89	83	84	86
89	83	83	85
88	83	82	85
88	83	80	81
88	82	80	77
87	81	79	76
86	74	79	74
70	69	78	70
60	68	77	67
57	54	72	53
Mean 85.8	82.4	83.7	82.0
Median 89.5	83.5	84.5	86.0

Study II thus demonstrated that the functional fidelity of a training device could be reduced to the point where the device was two-dimensional, without a loss in trainee proficiency. Trainees learned a procedure as well when using a photograph or a drawing as when using a fully functional, three-dimensional training device.

REDUCED HOUSING FIDELITY—STUDY III

Plan of Study

This study differed from the previous ones in that appearance fidelity rather than functional fidelity was the quality being investigated. The specific characteristic considered was the training device housing. During the task training, the operator neither performs any actions on nor receives any procedural signals from the housing, a structure which supports the SCI panel. Accordingly, the housing presumably would have no great importance to the trainee. Only if his attitude toward the device was negative because the housing looked unrealistic, and if his attitude affected his proficiency score, would the appearance of the housing be important.

Since the previous work had shown that less-than-perfect functional fidelity panel faces could be used to train men for the task without

affecting proficiency level, a Cold panel was selected as the device in this housing study. This panel could easily be moved from housing to housing, a High Fidelity housing already existed for it, and the panel was inexpensive to build.

The Cold panel was used in three housings of differing appearance fidelity: the High Fidelity housing, which was as similar to the Hot panel housing as a handmade cabinet could be; the Box housing, which held the Cold panel and concealed the back side of the panel; and the Frame housing which supported the Cold panel but did not conceal the back.

Each of three instructors trained three 5-man groups, one on each of the housings using the Cold panel. Proficiency scores were collected as previously described, using the Hot panel for the test.

Analysis and Results

The proficiency scores achieved by the trainees are listed in Table 4.[1] A simple analysis of covariance (Appendix Table C-7), in

Table 4

Individual Proficiency Scores of Trainees by Training Group: Study III

	High Fidelity Housing (N = 15)	Box Housing (N = 15)	Frame Housing (N = 15)
	91	91	92
	89	91	90
	89	91	89
	88	90	88
	87	89	88
	85	88	86
	85	88	84
	84	88	83
	83	86	82
	79	86	81
	79	77	80
	77	75	80
	72	74	79
	72	73	79
	69	70	77
Mean	81.9	83.8	83.8
Median	84.0	88.0	83.0

which proficiency scores were adjusted for individual differences associated with GT scores, showed no differences among adjusted housing means beyond those which chance would have produced ($p > .10$). The means for proficiency scores by housing group are shown in Appendix Table C-8.

[1] A test for homogeneity of regression within cells showed that the assumption of homogeneity was not tenable. A test for homogeneity of regression among the three housings showed that the assumption of homogeneity was tenable for housing effects.

The training times for each of the nine groups were correlated with the mean GT score for that group. Since the correlation ($r = .15$) was not significantly different from zero, no correction for GT differences was applied to the training times. An analysis of variance showed no significant differences in training time associated with housings or instructors. Mean times are shown in Appendix Table C-9.

Study III thus demonstrated that reducing the appearance fidelity of the housing of a training device had no effect upon trainee proficiency when the trainee's task involved no operations on the housing. The Frame housing served as well in Study III as did the High Fidelity housing.

CARDBOARD PANEL: A REPLICATION—STUDY IV

Plan of Study

A decision to develop a mock-up of the SCI fabricated from cardboard[1] and test its training effectiveness provided an opportunity to again test two- vs. three-dimensional devices and to study the effects of varying housing appearance.

Two devices from previous studies were used again, the Hot panel and the Cold panel. The third device was a Cardboard panel (mock-up) of the SCI, painted to match the high fidelity devices and with the face of the panel drawn to scale. The Hot panel represented full functional and housing fidelity. The Cold panel represented a three-dimensional reduction in functional fidelity and full housing fidelity. The Cardboard panel represented a two-dimensional reduction in functional fidelity and a reduction in appearance fidelity for both panel and housing.

Collection of data followed the pattern previously described. Each of three instructors trained three 5-man groups, one with each device.

Analysis and Results

An analysis of covariance on the proficiency scores[2] showed that, when intelligence was controlled, there were no differences associated with proficiency that could be attributed to panels, instructors, or panel-by-instructor interaction. Individual proficiency scores are listed in Table 5. The covariance computations are summarized in Appendix Table C-10. Means of the scores for the various groups are presented in Appendix Table C-11.

The correlation between group training times and GT scores was not significantly different from zero ($r = .23$), so a covariance analysis to control for intellectual function was not performed. An analysis of variance performed on the group training times showed no differences beyond chance attributable to either instructors or panels. Mean

[1]This approach was suggested by Mr. C.W. Polvogt, artist illustrator for HumRRO Division No. 5 (Air Defense).
[2]Tests of homogeneity of regression were performed. In each case, the tests did not lead to rejection of the null hypothesis of homogeneous regression.

Table 5

Individual Proficiency Scores of Trainees by Training Group: Study IV

Hot Panel (N = 15)	Cold Panel (N = 15)	Cardboard Panel (N = 15)
92	92	91
92	92	91
91	92	90
90	91	88
89	91	87
88	90	86
88	89	86
87	89	85
87	89	85
86	86	84
86	85	83
78	85	73
60	83	70
57	70	65
55	60	63
Mean 81.7	85.6	81.8
Median 87.5	89.5	85.5

training times for panels and instructors are presented in Appendix Table C-12.

Study IV confirmed the findings of Studies II and III. Reducing the functional fidelity of a training device to two dimensions had no effect on trainee proficiency on a procedural task, nor did reducing the appearance fidelity of panel and housing. A cardboard mock-up served as well to teach trainees a procedural task as did a high fidelity device.

REDUCED SIZE OF DEVICE—STUDY V

Plan of Study

The objective of this study was to determine the effects on proficiency of a reduction in the size of a training device. The results of the previous four studies were considered in designing the study and produced changes that simplified the work.

Line drawings were used as training devices in the size investigation for three reasons: Study II had demonstrated that a drawing was as effective as was a Hot, Cold, Frozen, or Photographic panel; of the five devices, drawings were the least expensive to prepare; drawings were very easy to produce in the three sizes selected for this research. The devices used were the Full-Sized panel, a black-on-white line drawing (22" x 30") of the Hot panel; the Half-Sized panel, 15" x 22" photographic prints made from the Full-Sized panel, and mounted on stiff cardboard; and the Small panel, 5" x 7" photographic prints made from the Full-Sized panel, and mounted on stiff cardboard.

Use of the Small panel necessitated a change in the training methods used in previous studies, in which all training was given with the training

device displayed so that every trainee in a five-man group could see it all the time. The 5" x 7" panel was too small for group instruction, so a copy was given to each student.

Since the change in procedure resulted in a change in student-to-device ratio, the effect of student-to-device ratio was evaluated by using two different training methods:

In Training Method I, the 5 to 1 student-to-device ratio and training procedures described for the earlier studies were used in training with the Full-Sized panel and the Half-Sized panel.

Training Method II was used to train men with the Half-Sized panel and the Small panel. Each trainee in a group was given a panel identical with that being used by the instructor. The instructor demonstrated the 92-step procedure, pointing to his panel as he proceeded, while each trainee followed the demonstration on his own panel. The instructor then selected one trainee to perform the procedure on his own panel, describing what he was doing and putting his finger on the panel part that was being operated, while the other trainees followed the performer on their own panels. When the performer made an error the instructor asked one of the observers to identify the correct action, and the performing trainee was required to give the correct verbal response and to continue the procedure. Each trainee served as a performer twice and as an observer eight times.

Training thus was performed under four conditions, with three 5-man groups trained under each condition: (1) a Full-Sized device used with Method I, (2) a Half-Sized device used with Method I, (3) Half-Sized devices used with Method II, (4) Small devices used with Method II.

As in the previous studies, men for this research were in training for MOS 192. No man was selected whose GT score was below 70. Except for this limitation, the 60 trainees were selected at random from the MOS 192 trainee group on post while the study was being performed.

Two members of the research staff served as instructors. Both had been instructors in the other four studies.

Of the several factors that had been statistically controlled in the previous four studies, only GT level was significantly associated with proficiency scores. To simplify the procedures, these controls were dropped in Study V. Trainees and instructors were randomly assigned to the 5-man groups, and groups were randomly assigned to the four training conditions.

One 5-man group was trained each day. Training extended from 0730 to approximately 1000 hours, and proficiency testing began at 1300 hours. The proficiency test was the same as for the previous studies.

Analysis and Results

Mean proficiency scores were computed for each of the four training conditions (Table 6). To estimate the effect of the student-to-device ratio, the mean proficiency scores for the groups trained on the Half-Sized panel by the two methods (conditions two and three) were submitted to a t-test. The means were not significantly different from each other ($t = .77$). This finding was interpreted to mean that the variation in

Table 6

Individual Proficiency Scores of Trainees by Training
Method and Group: Study V

Method I		Method II	
Full-Sized Panel	Half-Sized Panel	Half-Sized Panel	Small Panel
91	90	91	90
89	90	91	89
87	90	89	89
87	89	88	88
87	89	87	87
86	87	87	86
86	86	85	84
84	86	83	84
84	84	83	82
81	84	83	80
79	84	81	80
78	83	78	79
75	83	78	79
72	79	76	70
63	73	76	70
Mean 81.9	85.1	83.7	82.4
Median 84.0	86.0	83.0	84.0
Standard Deviation 7.5	5.1	5.5	6.9

method of training did not affect proficiency development. Therefore, the proficiency scores were tested with an analysis of variance to estimate the effect of size of the device on proficiency development.[1] The result was an $\underline{F}$ ratio of 1.08 which was not significant.

Study V demonstrated that the size of the training device did not affect proficiency attained. Trainees acquired as high a proficiency in a procedural task when trained with a small, individually issued device as they did when trained with a full-size device.

A FIELD EXPERIMENT—STUDY VI

Purpose of Study

To this point, the studies had shown that various reductions in fidelity of training devices had not affected the development of proficiency nor increased the training time on a procedural task. However, these studies had certain limiting factors: The instructors had been research personnel, the trainees had known that the training was experimental and not practical to them, and the training conditions had been controlled as in a laboratory. These factors were not typical of the usual Army training circumstances.

[1]Data from conditions two and three were pooled for this analysis.

A field study was therefore conducted to determine whether the reduction of device fidelity would still have no effect on proficiency development or training time under more realistic Army training conditions. In this study, military instructors trained soldiers who knew that they would be assigned to duty requiring them to perform the task on which training was given. In addition, the training was given under circumstances much more like those usually found in Army training.

Research Procedures

The low fidelity training device used in the experiment was the line drawing used in Study II, installed on the frame housing. It was used because it seemed likely that if one of the reduced fidelity devices were selected for Army use, the drawing would be chosen since it was economical to develop and reproduce. The high fidelity training used in the experiment was the actual tactical SCI, the equipment which was being used in the current Army training program. The panel of the tactical SCI, as installed for training, functions completely for one launcher and only partly for the other three launchers. At times, there is no power to the SCI because of malfunctions in other equipment in the system being used for training.

Each instructor used in the field study was currently qualified and instructing in the 177 MOS. Selection of instructors was not controlled by the researchers. Rather, permission was obtained to use trainees for the study as they were received by the batteries from Basic Combat Training. These trainees were routinely assigned to training groups and the groups were assigned to instructors. There is no reason to suppose that selection of instructors for the field study was other than random.

Similarly, there is no reason to suppose that assignment of trainees to the field study was other than random. Each trainee had completed Basic Combat Training and had been assigned to Advanced Individual Training for MOS 177.

The trainees were first given a tour of the training site. Each piece of Nike Hercules equipment was shown to them, and its function was explained briefly. Then, trainees were assigned to groups of from 9 to 13 men and training began, with the SCI panel drawing as the training device for the experimental treatment.

The experimental trainees were taught to perform Blue Status and Red Status procedures, as in the previous studies. Each instructor used the training techniques he already knew. A researcher observed this training, which was conducted in a room ordinarily used as an Army classroom and during the regularly scheduled training day. When the instructor estimated that a trainee had attained sufficient proficiency to proceed to other training, the trainee was taken to another building and given a proficiency test by one of the researchers. The observing researcher noted the total number of hours of training required for each trainee to reach this proficiency level.

For the control treatment, the tactical SCI was used in the training procedure. Trainees were given the same orientation and group

assignment as for the experimental treatment. The same task was taught to them, and a researcher observed the training. The training was given outdoors in a sandbagged area in front of the tactical SCI. The instructors followed their standard practices and techniques. When an instructor determined a trainee to be sufficiently proficient, the trainee was given a proficiency test by a researcher. The observing researcher recorded the training time for each trainee.

The same proficiency test was used as in the previous studies, and all tests were administered by the same researcher. Prior to the use of the high fidelity simulator as the testing device for this field study, 16 trainees who had been trained on the tactical SCI were given the proficiency test on both the tactical SCI and the high fidelity simulator. The correlation of these two sets of proficiency scores ($r = .80$) was considered sufficient evidence of the validity of the proficiency test administered with the high fidelity simulator to justify its use for proficiency testing in this field study.

A total of 36 men were trained with the experimental treatment by three instructors, each of whom trained one group of men. Training always began on Monday and was completed by Thursday of the same week. Another 35 men were trained by four different instructors who used the control treatment. The general training schedule was similar to that in the experimental treatment.

Analysis and Results

The mean proficiency score for the control group was 77.0 and for the experimental group 78.3. A t-test of the difference between these means ($t = .741$) showed the difference was well within the chance level.

The mean training time for the control group was 12 hours, 35 minutes and for the experimental group, 10 hours, 20 minutes. These two mean times were tested for differences with a t-test and found to be no more different than chance would allow ($t = 1.835$).

Study VI therefore produced under field training conditions results similar to those in the earlier studies, indicating that reductions in the fidelity of training devices did not lessen proficiency or increase training time on a procedural task.

The four instructors who used the line drawing for training were interviewed when training was completed. Each of these instructors had experience in training men with the tactical SCI as a part of their regular instructional duties. Three basic questions were asked of each instructor:

(1) Was the proficiency level of men trained with the drawing as high as that of men trained with the tactical SCI? One instructor gave a definite negative response; this same man was negative in his attitude to the drawing throughout the experiment, but he cooperated well. Two instructors gave a qualified and mild "no" answer to the question. The fourth instructor gave a very positive "yes."

(2) Was more training time required when the drawing was used than when the tactical SCI was used? One instructor said, "Yes." The other three gave negative replies, saying that there was no time difference.

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(3) Was more work involved when the drawing was used? Two instructors replied, "Yes " They said that the extra explanation (observed by research instructors) made instructing with the drawing more work than instructing with the tactical SCI. The other two instructors replied, "No." They said that instructing with the drawing was easier, not because of the device itself, but because the training was indoors where the instructor had better control of the attention of trainees.

DISCUSSION AND CONCLUSIONS

Functional Fidelity

The first study varied functional fidelity while maintaining the three-dimensional quality of the training devices tested, and demonstrated that men can be trained to perform a procedure as well with nonoperating devices as they can with a functional device. The second study extended the reduction of functional fidelity to two-dimensional devices, and showed that men can be trained to perform a procedure as well with full-sized photographs and drawings as with a functional device. The fourth study replicated the first two studies, varying the form of the two-dimensional device, and confirmed the earlier findings. The field study showed that the above findings apply where military instructors are training soldiers to whom the training is realistic.

Other investigators have reached similar conclusions. Denenberg (3) studied the transfer of training effects of an inexpensive mock-up of a tank hull and found that, for training on procedures for starting and stopping, the mock-up was as effective as was the tank itself. During study of teaching of ground cockpit procedures for an aircraft, training on a simple cockpit mock-up was found to transfer very well to procedures performed in the aircraft (Prophet and Boyd, 12). Training in flight procedures was successfully accomplished by use of a full fidelity simulator, a cold simulator, and a photographic mock-up (Dougherty, Houston, and Nicklas, 4). Aircraft basic instrument and radio range training have been taught equally well with two devices at different levels of fidelity (Wilcoxon, Davy, and Webster, 15). Torkelson (14) trained ROTC students and recruits in the nomenclature and function of antiaircraft weapons using a mock-up, a cutaway, and charts; performance of the ROTC group revealed no differences in effectiveness of the devices, while the recruits showed equal performance after training with the mock-up and cutaway but low performance on black-and-white charts. In retraining Air Force mechanics on B-47 fuel, hydraulics, or rudder power control systems, a comparison was made of several types of training devices which varied in level of functional fidelity, although this factor was not a concern in the study (Swanson 13). The devices were an operating mock-up, a nonoperating mock-up, a cutaway, an animated panel, charts, and symbolic diagrams. No differences in proficiency were found among those training with different devices, and there were still no differences six to eight weeks later.

The evidence from the Task RINGER studies as well as from other research provides the basis for a rather firm conclusion about functional fidelity: When men are being trained to perform a procedure and a training device is to be used as a method of training them, the requirements for functional fidelity in the device are quite low.

There are certain limiting factors to be considered:

(1) The conclusion applies only to procedural tasks. No evidence is presented that should encourage generalization to psychomotor tasks, decision-making tasks, or any work classification other than procedures.

(2) The training device did not train these men by itself; the whole training process produces the proficiency of trainees. The orientation, the techniques of instructors, and the psychological atmosphere of the situation all affect trainees' acquisition of proficiency at the task.

(3) In each study some variations occurred when verbal signals replaced visual and auditory signals. While these variations produced no significant differences in performance in the present studies, changes in the training environment in which the training device is used might produce differences in the effectiveness of devices at different levels of functional fidelity.

Even considering these limitations, there is still a strong implication emerging from the conclusion. The cost of equipment for training must be large when tactical equipment is the training device. For example, cost of the SCI equipment was estimated by a training officer as about $11,000; to use it in a full fidelity mode, a power generator, a Launcher Control Trailer, one launcher, and a missile are required. The authors estimate the cost of the full fidelity simulator (Hot panel) used in this research at approximately $3,000 and that of the Cold panel and the Frozen panel in high fidelity housing at $1,000 each. The Photographic panel and housing cost estimate is $100, and that of the Drawing panel and housing is $75. Cost of the Cardboard device is still lower. Thus, for a procedural task, training can be just as effective with a device costing a few dollars as it is when the tactical equipment itself is used.

The designer of training programs ought to be able to select training methods, including training devices, so that the program uses less expensive training devices of low functional fidelity for procedures training, at a substantial monetary saving. The results do not imply that low functional fidelity devices should be used for training in psychomotor and other skills.

Appearance Fidelity

While appearance fidelity was involved in the three-dimensional vs. two-dimensional device experiments, results were considered to refer to functional fidelity.

Housing fidelity was studied as a dimension within the category of appearance fidelity.[1] In Study III, when the housing of the device was

[1]Since the job incumbent did not operate upon the housing while performing the task used in this research, varying the housing did not affect the functional fidelity of the device but did affect the appearance fidelity.

varied at three categorical levels, no differences in proficiency were found that were due to housings, nor was there any difference in the amount of time used in training men with each housing. In Study IV this result was confirmed with a cardboard housing. The field study also confirmed the finding.

. . Thus, when the training of the procedural task does not require the job incumbent to perform any operations on the housing, proficiency development is not related to appearance fidelity on the housing dimension of the training device. The implication is that the training designer should use the lowest cost housing available which will adequately support and protect the man-machine interface.

In the study of the appearance fidelity dimension of size, the method of training for the smaller devices was changed so that each trainee had his own training device to use rather than all five men using a single device. Analysis of the data by the three size categories showed that men can be trained with a small device as effectively as they can with a full-size device.

The size study extends the implications of the other studies. It appears that when a training device is to be used to train small groups of men to perform a procedural task, small pictures or drawings can be used as the training device, each trainee having his own device from which to study and perform. The limitation on size reduction seems to be only that the trainee must be able to see the elements on the device clearly and to read any lettering.

Instructor Work Load

The research instructors observed that the work load placed on them by all the devices that were reduced in fidelity was greater than the work load required when using the Hot panel because the instructor, rather than the device, had to provide signals. The Hot panel required the least work from an instructor because the panel itself presented many signals to the trainee and gave him knowledge of results directly. For example, the Hot panel made a noise like the motor of a launcher when the Launcher Elevation switch was placed in UP position; this noise was both a signal to the trainee and knowledge that the previous action, positioning the switch to UP, was correct. None of the other panels gave these signals to the trainee, and so the instructor was required to give them verbally. This requirement meant that the instructor's attention was focused directly on the immediate training process during every moment of training when a panel other than the Hot one was being used. The instructor was continually giving the trainee verbal signals.

When a three-dimensional panel was being used, the instructor told the trainee to manipulate the switches (or, for the Frozen panel, to try to operate them) just as if the panel were functional. The trainees then tended to "go through the motions" without further instruction. This allowed the instructor to observe the trainee's actions readily and to correct him if necessary. However, when a two-dimensional panel was used, trainees had to be reminded several times to "go through

the motions" by putting a finger on the panel part which was being operated. Even when the trainee did this, the instructor had to observe more closely than before and had to rely on verbal substitutions from the trainee for actions the trainee should be taking.

This added work load did not affect the time required to train or the proficiency level developed. Research instructors were able to absorb the added work without an effect on the training output. The field study data showed that military instructors were able to perform equally well under high fidelity and low fidelity conditions, even though definite lack of confidence in the low fidelity device was expressed by some instructors.

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AND
APPENDICES

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Appendix A

COMPLETE SEQUENCE OF PROCEDURAL TASK

Standard Blue Status Procedures

Operator is standing before the SCI, which is open but "cold." He is monitoring for Blue Status light and Alarm buzzer to sound.

SIGNAL	ACTION
1. Buzzer and Blue Status light.	1. Throw Power switch to ON.
	2. Throw Panel Light switch to ON.
	3. Put hand under Panel Light to check for illumination level.
	4. Adjust light level with control knob.
	5. Throw all four Intercom (IC) switches to ON.
	6. Throw all four Launcher Power switches to ON.
	7. Plug Handset-Headset (HH) set into Station 2.
	8. Announce "Blue Status received, Section A" on HH set.
	9. Put IC switch to TALK and hold.
	10. Announce "Blue Status" on IC.
	11. Check and adjust mike level while announcing.
	12. Release IC switch to LISTEN.
	13. Press Alarm shutoff button till buzzer stops.
	14. Monitor for "All crewmen present" on IC.
2. "All crewmen present" on IC.	15. Announce "All crewmen present, Section A" on HH set.
	16. Monitor for "Battle Stations" on HH set.
3. "Battle Stations" on HH set.	17. Announce "Battle Stations received, Section A" on HH set.
	18. Operate IC switch.
	19. Monitor for green ON DECK light.
	20. Announce "Battle Stations" on IC.
4. Green ON DECK light.	21. Monitor for "Launcher prepared" on IC.
5. "Launcher #1 prepared" on IC.	22. Press PREPARED button for #1.

SIGNAL	ACTION
	23. Monitor for green #1 PREPARED and SAME light.
6. Green #1 PREPARED and SAME light on.	24. Monitor for "Launcher prepared" on IC.
7. "Launcher #2 prepared" on IC.	25. Press PREPARED button for #2.
	26. Monitor for green #2 PREPARED and SAME light.
8. Green #2 PREPARED and SAME light on.	27. Monitor for "Launcher prepared" on IC.
9. "Launcher #3 prepared" on IC.	28. Press PREPARED button for #3.
	29. Monitor for green #3 PREPARED and SAME light.
10. Green #3 PREPARED and SAME light.	30. Monitor for "Launcher prepared" on IC.
11. "Launcher #4 prepared" on IC.	31. Press PREPARED button for #4.
	32. Monitor for green #4 PREPARED and SAME light.
12. Green #4 PREPARED and SAME light on.	
	33. Monitor for "Launcher ready" on IC.
13. "Launcher #1 ready" on IC.	34. Operate IC switch.
	35. Announce "Stand clear, Launcher #1 going up" on IC.
	36. Throw Launcher Elevation (LE) switch for #1 to UP.
14. Noise on IC.	37. Monitor noise on IC till it stops.
	38. Throw LE switch for #1 to OFF.
	39. Monitor for "Launcher ready" on IC.
15. "Launcher #2 ready" on IC.	40. Operate IC switch.
	41. Announce "Stand clear, Launcher #2 going up" on IC.
	42. Throw LE switch for #2 to UP.
16. Noise on IC.	43. Monitor noise on IC till it stops.
	44. Throw LE switch for #2 to OFF.
	45. Monitor for "Launcher ready" on IC.
17. "Launcher #3 ready" on IC.	46. Operate IC switch.
	47. Announce "Stand clear, Launcher #3 going up" on IC.
	48. Throw LE switch for #3 to UP.
18. Noise on IC.	49. Monitor noise on IC till it stops.
	50. Throw LE switch for #3 to OFF.
	51. Monitor for "Launcher ready" on IC.

SIGNAL	ACTION
19. "Launcher #4 ready" on IC.	52. Operate IC switch.
	53. Announce "Stand clear, Launcher #4 going up" on IC.
	54. Throw LE switch for #4 to UP.
20. Noise on IC.	55. Monitor noise on IC till it stops.
	56. Throw LE switch for #4 to OFF.
	57. Wait for Section Chief.
21. Section Chief comes into revetment.	58. Throw all four IC switches to OFF.
22. Section Chief turns safety keys to FIRE.	59. Monitor for four amber LAUNCHER READY lights.
23. All four LAUNCHER READY lights on.	60. Throw Heaters and Gyros (H&G) switch for #1 to ON.
	61. Record time on log.
	62. Monitor for green READY TO FIRE light for #1.
24. Green READY TO FIRE light #1 on.	63. Throw DESIGNATE switch to #1 strip.
	64. Press LAUNCHER DESIGNATE button.
	65. Monitor for green LAUNCHER DESIGNATE light.
25. Green LAUNCHER DESIGNATE light on.	66. Press SLEW button and hold through check.
26. Smooth movement of needle full left to full right twice.	67. Throw SECTION READY switch to READY.
	68. Monitor for green SECTION READY light.
27. SECTION READY green light on.	69. Wait for Section Chief to OK.
28. Section Chief says "Blue Status checks complete."	70. Announce "Blue Status checks complete, Section A" on HH set.

Standard Red Status Procedures

Operator is standing in front of open SCI. Power is on. Blue Status is on. Checks are complete. Operator is wearing Handset-Headset (HH) set and is monitoring for Red Status.

SIGNAL	ACTION
	1. Monitor for Red Status light.
1. Red Status light on.	2. Announce over HH set, "Red Status received, Section A."
	3. Monitor for green SELECTED light.
2. Green SELECTED light on.	4. Throw Heaters and Gyros (H&G) switch for #2 to ON.
	5. Record time on log.

SIGNAL	ACTION
	6. Monitor for buzzer and green FIRE, LAUNCH ORDER, and MISSILE AWAY lights.
3. Buzzer, green FIRE, LAUNCH ORDER, and MISSILE AWAY lights on.	7. Throw SECTION READY switch down (OFF).
	8. Throw LAUNCHER ELEVATION switch for #1 to DOWN.
	9. Monitor for green READY TO FIRE light on #2.
	10. Move LAUNCHER ELEVATION switch for #1 to OFF.
4. Green #2 READY TO FIRE light on.	11. Throw DESIGNATE switch to #2 strip.
	12. Press LAUNCHER DESIGNATE button.
	13. Monitor for green LAUNCHER DESIGNATE light.
5. Green LAUNCHER DESIGNATE light on.	14. Press SLEW button.
	15. Monitor SLEW METER for correct check.
6. Smooth movement of needle left to 0, right to 0, twice.	16. Throw SECTION READY switch up (ON).
	17. Monitor for green SECTION READY light.
7. Green SECTION READY light on.	18. Monitor for green SELECTED light.
8. Green SELECTED light on.	19. Throw H&G switch for #3 to ON.
	20. Record time on log.
	21. Monitor for Buzzer and green FIRE, LAUNCH ORDER, and MISSILE AWAY lights.
9. Buzzer and green FIRE, LAUNCH ORDER, and MISSILE AWAY lights on.	22. Throw SECTION READY switch down (OFF).

Appendix B

ORIENTATION TO THE NIKE HERCULES SITE AND
THE SECTION CONTROL INDICATOR (SCI)

The Nike Hercules is primarily an antiaircraft missile and can be armed with a nuclear warhead. The site consists of approximately eight major pieces of equipment. The layout varies from site to site, depending on geographic conditions, and on this chart you see one example of a basic site layout. This could represent an area of several miles, and the only consistency is the separation of the IFC (Integrated Fire Control) area (the upper half of the diagram) from the launching area.
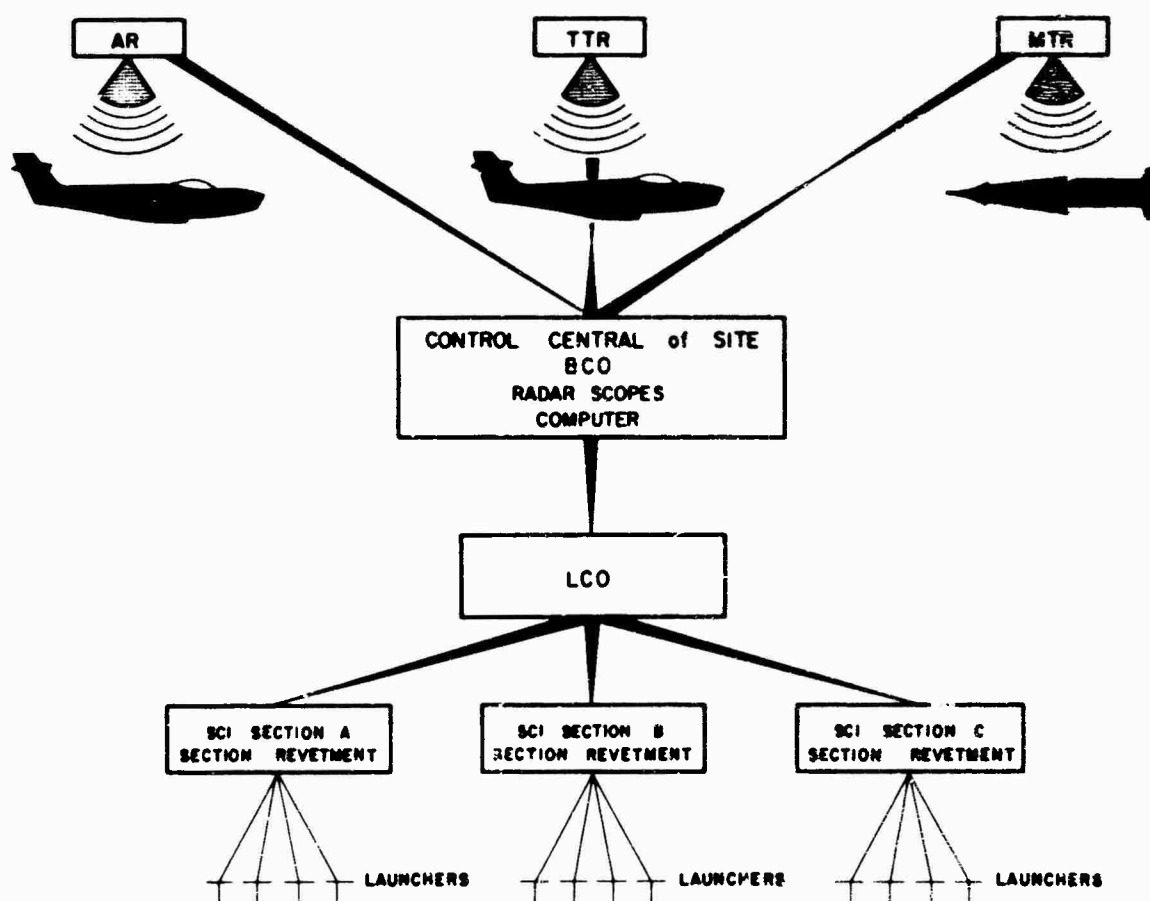
Acquisition Radar (AR)

The AR operates continually as it searches the area of protection. When a target has been acquired, the AR sends azimuth and range data to the Target Tracking Radar through the computer.

Target Tracking Radar (TTR)

The TTR locks on the target and tracks it until the target is either released by the Battery Control Officer (BCO) or destroyed by the selected missile. The tracking data is fed to the computer to enable it to plot the missile course to the intercept point.

Missile Tracking Radar (MTR)

When the missile is fired the MTR controls the flight pattern and sends missile position data to the computer.

The three radars have operators constantly monitoring the display scopes.

Battery Control Officer (BCO)

The computer information is monitored by the BCO who makes the final decision whether a missile should be launched.

Launcher Control Officer (LCO)

The LCO relays the commands from the BCO to the Section Control Indicator (SCI) operators. The LCO controls 12 missiles through three SCI panels, and it is his responsibility to select a missile for firing.

Section Control Indicator (SCI)

The operator of the SCI coordinates his duties with his Section Chief and the LCO. He checks the SCI daily and maintains communication between the LCO and the launcher crew. The SCI supplies the power to the four missiles on the launchers. The SCI operator is responsible for the crewmen and the status of the missile during this procedure.

You are here to learn the SCI procedures in Blue Status and Red Status. Blue Status is the procedure taken to prepare a missile for firing, and Red Status is the actual firing procedure.

Do you have any questions?

Appendix C

DATA AND ANALYSES

Table C-1

Analysis of Covariance of Proficiency Scores
Controlling for Variance on GT Scores: Study I

Source of Variance	df	Sums of Squares and Products			r	b	Error of Estimate			F
		SSx	SP	SSy			SS'y	df	MS	
Panels (P)	2	11.63	41.85	152.10	.99	3.60	132.00	2	66.00	1.07
Instructors (I)	2	18.45	17.70	77.10	.47	.96	69.99	2	35.00	<1.00
Interaction (P x I)	4	103.10	41.05	270.90	.25	.40	257.54	4	64.38	1.04
Within Cells	51	19911.00	4540.50	4176.50	.50	.23	3141.07	50	61.59	
Total	59	20044.18	4641.10	4670.60	.48	.23	3600.60	58		

Table C-2

Proficiency Score Means for Instructors and Panels: Study I

Instructor	Mean for Panel Group						Average for Instructors		r
	Hot		Cold		Frozen				
	Unadj.	Adj.	Unadj.	Adj.	Unadj.	Adj.	Unadj.	Adj.	
1	86.4	86.0	82.4	82.9	85.8	85.5	84.9	84.9	.45
2	83.6	83.9	88.0	87.2	76.8	78.6	82.8	83.2	.48
3	86.5	86.1	86.6	86.2	83.6	83.9	85.6	85.4	.50
Average for Panel Groups	85.8	85.5	85.9	85.6	82.4	82.9	84.7	84.7	.50
r		.47		.49		.52			.48

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Table C-3

Mean Training Times for Panels and
Mean Training Times for Instructor Groups: Study I

Instructor	Mean Training Times (hr. and min.)	Panel	Mean Training Times (hr. and min.)
1	2' 37"	Hot	2' 34"
2	2' 40'	Cold	2' 35"
3	2' 41"	Frozen	2' 41"
Total	2' 41"	Total	2' 41"

Table C-4

Analysis of Covariance of Proficiency Scores
Controlling for Variance on GT Scores: Study II

Source of Variance	df	Sums of Squares and Products			r	b	Error of Estimate			F
		SSx	SP	SSy			SS'y	df	MS	
Panels (P)	3	25.85	-71.15	201.50	-.99	-2.75	235.36	3	78.45	1.49
Instructors (I)	2	8.85	28.40	168.90	.73	3.21	156.27	2	78.14	1.48
Interaction (P x I)	6	161.05	96.45	205.60	.53	.60	102.31	6	28.27	< 1.00
Within Cells	68	24101.80	5544.50	4811.20	.51	.23	3535.72	67	52.77	
Total	79	242975.55	5598.20	5387.20	.50	.24	4029.66	78	237.63	

Table C-5

Proficiency Score Means for Instructors and Panels: Study II

Instructor	Mean for Panel Group								Average for Instructors	
	Hot		Frozen		Photographic		Drawing			
	Unadj.	Adj.	Unadj.	Adj.	Unadj.	Adj.	Unadj.	Adj.	Unadj.	Adj.
1	86.4	86.0	85.8	85.6	81.0	81.3	79.8	80.2	83.2	83.1
2	83.6	83.4	76.8	75.4	84.4	84.1	78.0	77.9	80.7	80.6
3	86.5	87.1	83.6	83.8	84.7	84.7	85.2	84.7	85.0	85.1
Average for Panel Groups	85.8	85.7	82.4	82.3	83.7	83.7	82.0	81.8	83.5	83.5

Table C-6

Mean Training Times for Panels by Instructor Groups: Study II

Instructor	Training Times in Hours and Minutes				Mean Training Times
	Hot Panel	Frozen Panel	Photographic Panel	Drawing Panel	
1	2' 40"	2' 40"	3' 15"	2' 35"	2' 47"
2	2' 45"	2' 40"	2' 40"	3' 30"	2' 56"
3	2' 17"	3' 15"	2' 47"	2' 23"	2' 41"
Mean	2' 34"	2' 53"	2' 56"	2' 49"	2' 48"

Table C-7

Analysis of Covariance for Housings: Study III

Source of Variance	df	Sums of Squares and Products			Error of Estimate			F
		SSx	SP	SSy	SS'y	df	MS'y	
Housings	2	10.711	19.600	36.133	28.245	2	14.122	< 1.00
Within	42	14929.067	2738.400	1791.067	1289.770	41	31.458	
Total	44	14939.778	2758.000	1827.200	1318.015	43		

Table C-8

Means, Correlation Coefficients, and Regression Coefficients: Study I"

Housing	Mean GT Score	Mean Proficiency Score		Correlation Coefficient	Regression Coefficient
		Unadj.	Adj.		
High Fidelity	99.5	81.9	82.1	.50	.195
Box	100.6	83.8	83.7	,55	.208
Frame	100.5	83.9	83.8	.56	.143
Average	100.2	83.2	83.2	.53	.185

Table C-9

Mean Training Times for Housings by Instructor Groups: Study III

Instructor	Training Times in Hours and Minutes			Mean Training Times
	High Fidelity Housing	Box Housing	Frame Housing	
1	3' 00"	2' 50"	3' 00"	2' 56"
2	2' 50"	2' 50"	3' 00"	2' 53"
3	3' 10"	2' 30"	2' 30"	2' 43"
Mean	3' 00"	2' 43"	2' 50"	2' 51"

Table C-10

Analysis of Covariance of Proficiency Scores
Controlling for Variance on GT Scores: Study IV

Source of Variance	df	Sums of Squares and Products			r	b	Error of Estimate			F
		SSx	SP	SSy			SS'y	df	MS	
Panels (P)	2	24.05	20.89	146.98	.35	.87	136.57	2	68.27	< 1.00
Instructors (I)	2	54.59	24.89	1.38	1.00	.46	1.34	2	.67	< 1.00
Interaction (P x I)	4	76.48	104.91	292.36	.70	1.37	235.73	4	58.93	< 1.00
Within Cells	36	15378.80	4626.00	4455.20	.56	.30	3063.68	35	87.53	
Total	44	15533.91	4776.69	4905.91	.55	.31	3437.32	43		

Table C-11

Proficiency Score Means for Instructors and Panels: Study IV

Instructor	Mean for Panel Group						Average for Instructors	
	Hot		Cold		Cardboard			
	Unadj.	Adj.	Unadj.	Adj.	Unadj.	Adj.	Unadj.	Adj.
1	83.6	82.5	88.0	87.8	78.6	79.3	83.4	83.2
2	82.6	82.4	86.8	86.3	80.8	80.7	83.4	33.2
3	79.1	79.8	82.0	82.4	86.0	86.0	82.3	82.5
Average for Panel Groups	81.7	81 5	85.6	85.5	81.8	81.0	83.0	83 0

Table C-12

Mean Training Times for Hot, Cold, and
Cardboard Panels by Instructor Groups: Study IV

Instructor	Training Times in Hours and Minutes			Mean Training Times
	Hot Panel	Cold Panel	Cardboard Panel	
1	2' 45"	2' 30"	3' 45"	3' 00'
2	2' 15"	2' 45"	2' 30"	2' 30'
3	2' 30'	2' 30"	2' 15"	2' 20'
Mean	2' 30'	2' 30'	2' 50'	2' 37"